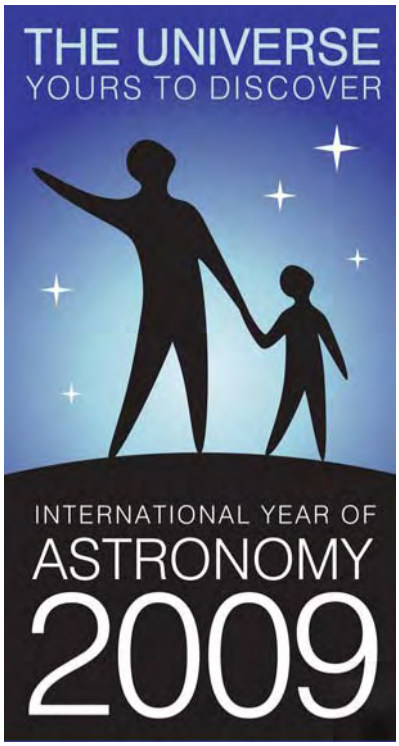
July 2009
IYA Discovery Guide



This Month's Theme:

Black Holes

Featured Activity:

Black Hole Star Map

Featured Observing Object:

The Milky Way Galaxy

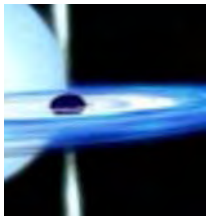
The International Year of Astronomy is a global celebration of astronomy and its contributions to society and culture, highlighted by the 400th anniversary of the first use of an astronomical telescope by Galileo Galilei.
Join us as we look up! http://astronomy2009.us

The Astronomical Society of the Pacific increases the understanding and appreciation of astronomy by engaging scientists, educators, enthusiasts and the public to advance science and science literacy.
http://www.astrosociety.org

July's Topic:
Black Holes

Before the bright lights of cities outshone the wonders of the night sky, the Milky Way was a common sight for most of the world. Legends from various cultures described this region as a road, a river, or a flock of birds. The Greeks and Romans thought the haze looked like milk, which is where the name Milky Way comes from. When Galileo pointed his small telescope towards this band of light, he didn't see milk or birds. "The Milky Way is nothing else but a mass of innumerable stars planted together in clusters." We know now that the Milky Way Galaxy is indeed a collection of gas, dust and billions of stars, including our Sun.

But there is more to the galaxy than stars, gas, and dust. There are also black holes. In the dense center of the Milky Way, there is good evidence that a supermassive black hole exists with over 2 million times the mass of our Sun. Scientists have good evidence that most large galaxies contain giant black holes in their centers. But we can't point a telescope at a black hole and see it directly. We only see their effect on the things around them, like stars and gas. In fact, the mass of a black hole is determined using physics developed by Galileo's contemporary, Johannes Kepler.



There is a smaller, more common type of black hole with only a few times the mass of our Sun. These are the remains of giant stars that end their lives in a supernova explosion. If there is enough mass left at the core of the star after the explosion, it collapses to a point, creating a region of gravity so strong that not even light can escape.

This makes finding black holes a little bit tricky. But scientists love a challenge. As it turns out, when material falls into a black hole, it gets heated up to millions of degrees releasing high energy radiation like x-rays before it is lost forever. So searching for sources of x-rays is another way to detect black holes, and this is how NASA's Chandra Observatory studies the black hole at the center of our galaxy. Scientists are also using x-rays to research the behavior of black holes with the Suzaku and XMM-Newton space observatories. The Hubble Space Telescope has even discovered medium sized black holes. With future generations of telescopes, like the James Webb Space Telescope, astronomers will be able to go deeper in their understanding of black holes and the role of the black holes in galaxy evolution.

While we can't see black holes directly, you can use the star maps in this guide to find out where they are located in the night sky.

Learn more about Black Holes from NASA.
Find more activities featured during IYA 2009.
See what else is planned for the International Year of Astronomy.

CHANDRA EXPLORES "DOWNTOWN" IN THE MILKY WAY

The word galaxy comes from the Greek word meaning "milky circle" or, more familiarly, "milky way." The white band of light across the night sky that we call the Milky Way was poetically described long before Galileo. But with his small telescope, what he discovered was a multitude of individual stars, "so numerous as almost to surpass belief."

Today we know that the Milky Way is our home galaxy - a vast rotating spiral of gas, dust, and hundreds of billions of stars. The Sun and its planetary system formed in the outer reaches of the Milky Way about 4.5 billion years ago.

In the center of the Galaxy is the bar-shaped Galactic bulge which harbors a supermassive black hole with a mass equal to that of about 3 million suns. Surrounding the central bulge is a relatively thin disk of stars about 2,000 light years thick and roughly 100,000 light years across. Giant clouds of dust and gas in the disk and bulge absorb starlight and give the Galaxy its patchy appearance.

The Milky Way is home to generations of stars past. Many stars become small, dense white dwarfs after a bloated 'red giant' phase. Other, more massive stars explode as supernovas, enriching the Galaxy with heavy elements manufactured in their cores, and leaving behind either neutron stars or black holes.

The Galaxy's bright stellar disk is embedded in a faint disk of old stars which is about 3 times thicker than the thin disk. Surrounding the thick Galactic disk is an extremely faint halo that contains the oldest stars in the Galaxy. The Galactic halo is dominated by dark matter, a still mysterious form of matter that cannot be observed directly.

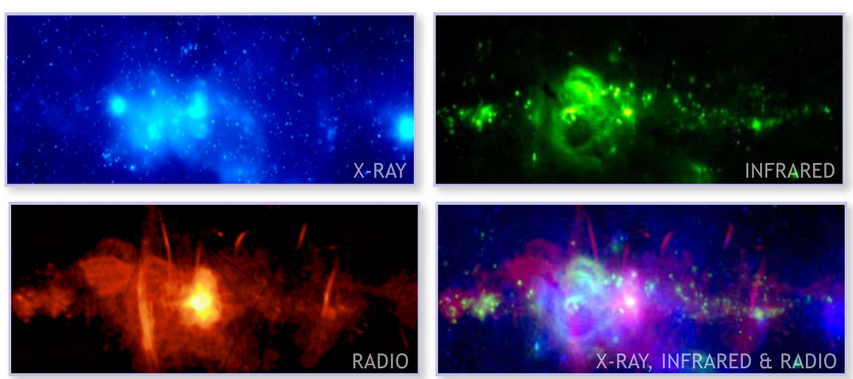
CHANDRA MOSAIC OF THE GALACTIC CENTER

"There is a way on high, conspicuous in the clear heavens, called the Milky Way, brilliant with its own brightness."

Ovid (43 BC - 17 AD), Metamorphoses

CHANDRA EXPLORES "DOWNTOWN" IN THE MILKY WAY

Most of the action in our Milky Way takes place in its crowded center, the bustling "downtown", so to speak, of our Galactic metropolis. With Chandra's keen X-ray vision, scientists are trying to determine how this relatively small patch of Galactic real estate affects the evolution of the Galaxy as a whole. For example, Chandra sees large quantities of extremely hot gas apparently escaping from the center. This outflow of gas -- enriched with elements like iron, carbon, and silicon from the frequent destruction of stars -- is distributed into the rest of the Galaxy. These elements are crucial to the formation of stars and planets, including Earth.



Dust and gas produced by millions of massive stars makes it difficult for optical telescopes to see into this region. However, other wavelengths can reveal certain features in the Galactic Center. A composite of images made at X-ray (blue), infrared (green), and radio (red) shows the relation between hot gas (X-ray), cool gas and dust (infrared) and high energy electrons trapped in the magnetic field in the Galactic Center (radio). Because it is only about 25,000 light years from Earth, the center of our Galaxy provides an excellent laboratory to learn about the cores of other galaxies.

Credits (Left-Right, Top-Bottom): Chandra broadband X-ray (NASA/UMass/D. Wang et al.), Infrared (MSX), Radio (VLA/NRL/N. Kassim)

THE GALACTIC CENTER: A panoramic X-ray view, covering a 900-by-400 light-year swath, shows that the center of the Galaxy is a teeming and tumultuous place. There are supernova remnants: SNR 0.9-0.1, Sagittarius A East, and probably the X-ray Thread. There are many bright X-ray sources, which astronomers believe are binary systems — or pairs of orbiting objects — that contain a black hole or a neutron star (the 1E sources). There are hundreds of unnamed point-like sources that scientists think are solo neutron stars or white dwarfs, which all light up the region. In addition, the massive stars in the Arches and other star clusters (the DB sources) will soon explode to produce more supernovas, neutron stars, and black holes.

Additional telescopes have also found other exotic members of this cosmic zoo. Infrared and radio observations find giant molecular clouds (Sagittarius A, B1, B2, and C, and the Cold Gas Cloud near the Radio Arc) where stars form. Normally too cool to be detected in X-rays, the edges of these clouds have been heated, allowing Chandra to see their X-ray glow.

All this commotion takes place in a diffuse cloud of hot gas that shows up as extended X-ray emission. This diffuse X-ray glow gets brighter toward the Galactic Center. Sagittarius A (Sgr A), the bright blob in the center, is composed of three main parts: Sgr A East, Sgr A West, and Sgr A*. Sgr A East is the remnant of a supernova that stirred things up about 10,000 years ago. Sgr A West is a spiral-shaped structure of gas that may be falling toward Sgr A*, the supermassive black hole that marks the center of the Milky Way Galaxy. Sgr A* contains about 3 million times the mass of the Sun, and is gaining weight daily as it pulls in more material.

Coordinates (J2000): RA 17h 45m 23s Dec -29°01'17"	Observation Time: 94.2 hours total
Constellation: Sagittarius	Color Code: Energy
Observation Date: July 2001 (30 separate pointings)	Instrument: ACIS

MORE ON THE MILKY WAY

CHANDRA X-RAY CENTER

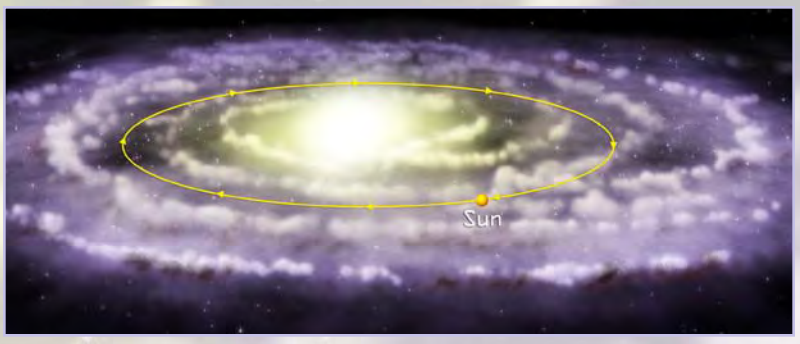
How can you take a picture of our Galaxy if we are in it? Since our Solar System is embedded within our Galaxy, we can only show an artist's representation of what it looks like from the outside. From our vantage point, we only have an edge-on view of the Milky Way, but this is still very useful. Different types of astronomical observations – some that trace the spiral arms, others that detect stars or gas and dust – can be pieced together. Combined with images from other galaxies that are the same type as ours, this allows scientists to construct a view of what the Milky Way would look like from the outside.

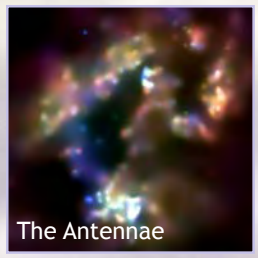
How far are we from the Galactic plane and the center of the Galaxy? The Earth is a few tens of light years above the middle of the thin disk where most of the stars in the Galaxy are found, also known as the "Galactic plane." This is actually rather close given the scale of the Galaxy. On the other hand, the Earth is approximately, 25,000 light years away from the center of the Galaxy. To put this into context, that places us in a spiral arm about 2/3 of the way to outer edge of the Galaxy.

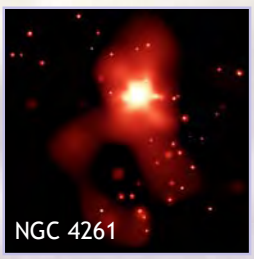
How do we know there's a supermassive black hole in the center of the Milky Way? Astronomers have used careful observations of the motions of stars around the center of our Galaxy to make inferences about the mass of the object that lies at the center. They have concluded that these stars orbit a dark massive body, with a mass approximately 3 million times that of the Sun. The only known object that could be so massive and still be dark is a supermassive black hole.

Could a black hole in our Galaxy ever be strong enough to pull our solar system into it? It would have to be so close that its gravity could overcome the orbital acceleration of our solar system around the center of the Galaxy. That would be well within a light year, even for a million solar mass black hole, which we would definitely know about!

Is our solar system traveling within our Galaxy? Our solar system travels in an orbit around the center of the Galaxy at a velocity (i.e. speed) of a few hundred kilometers per second, completing one orbit around the center of the Milky Way about every 230 million years. In addition, the solar system is moving at about 20 kilometers per second with respect to the nearby stars. There is also a small amount of motion with respect to the plane of the Galaxy. Currently, the solar system is heading outwards but the gravitational pull of the stars in the galactic plane will eventually cause it to stop and then move back towards the galactic plane. Our whole Galaxy is also traveling through space. Within the local group of galaxies, the Milky Way's velocity is several hundred kilometers per second.







What would happen if the Andromeda Galaxy and the Milky Way galaxy collided? This collision won't happen for several billion years, but if it does, enormous numbers of new stars should form, as gas from the two galaxies is squeezed together. Large numbers of massive stars should explode as supernovas, spreading heavy elements like iron and magnesium outwards. An example of this effect can be seen in the Antennae galaxies. Chandra observations (left) of these colliding galaxies have revealed hot gas containing extremely high concentrations of heavy elements. These elements were created by nuclear fusion reactions in the centers of massive stars, and were dispersed by supernova explosions. The motions of the stars in the original spiral galaxies are radically changed by a galactic collision, and eventually a large elliptical galaxy should form. This process is believed to have taken place a few billion years ago in NGC 4261. This large elliptical galaxy shows no trace of its violent history in optical images, but Chandra observations (right) are thought to show remnants of a galactic collision.

MORE INFORMATION ON THE MILKY WAY IS AVAILABLE AT
http://chandra.harvard.edu/xray_sources/milky_way.html
http://chandra.harvard.edu/photo/category/milkyway.html

Credits - Milky Way illustration: CXC/M.Weiss; Galactic Center image: NASA/U Mass/D.Wang et al.; Milky Way with Sun Orbit illustration: CXC/M.Weiss; The Antennae Diffuse: NASA/CXC/SAO/G.Fabbiano et al.; NGC 4261: NASA/CXC/A.Zezas et al.; SgrA*: NASA/CXC/MIT/F.K.Baganoff et al.

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For more information, visit:
http://chandra.harvard.edu

July 2009 Featured Observing Object:

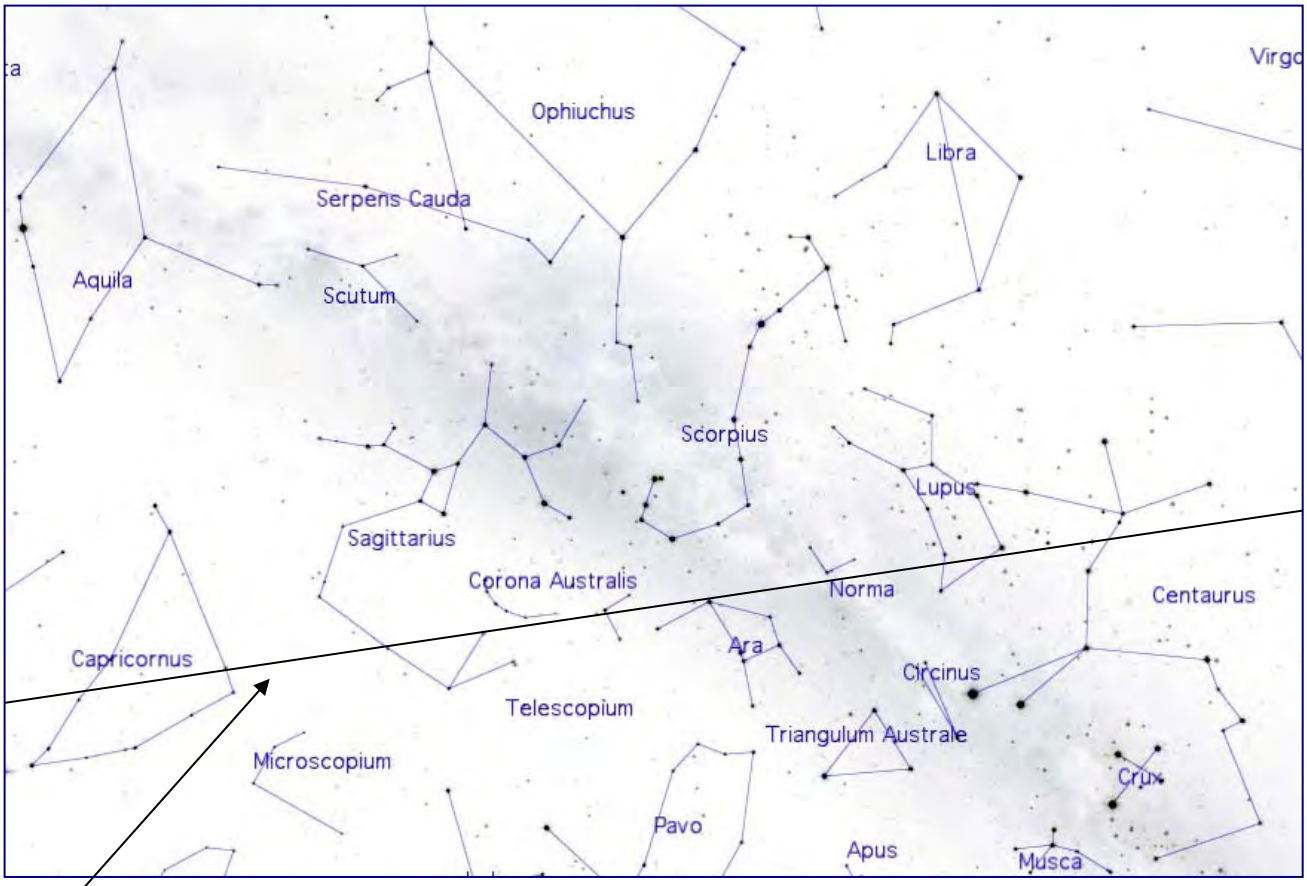
Milky Way Galaxy
Finder Chart

For information about the Milky Way: http://www.seds.org/messier/more/mw.html

To view: unaided eyes or binoculars

Look up at night – all the stars you see are in our own Milky Way Galaxy. The Sun and its planets, including Earth, are imbedded in the Milky Way Galaxy. You are looking through the thickest part of our Galaxy when you view the hazy band of light that extends from horizon to horizon. You will only be able to see this hazy band far from city lights.

The hazy band of the Milky Way passes through the constellations of Cygnus, Aquila, Scorpius, and Crux, the Southern Cross. Use binoculars to look in the direction of one of those constellations and you will see a multitude of stars appearing to be crowded together.



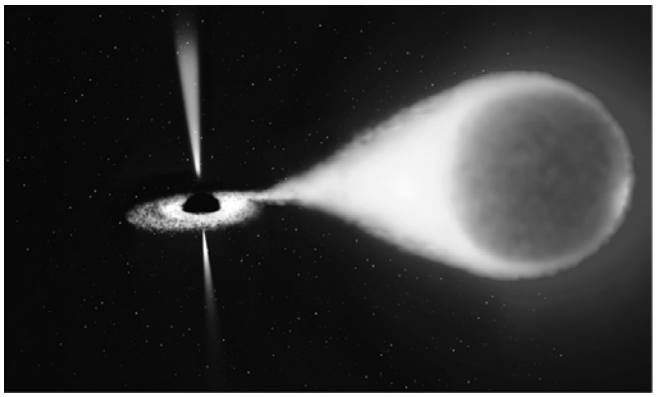
Approximate horizon from about 35 degrees north latitude (Los Angeles, California)

Star Maps:
Where are the Black Holes?

About the Activity
Make black holes real in the night sky by showing your visitors the locations of known black holes with these Star Maps.

Topics Covered
Making it real in the night sky: pointing out the locations of known black holes

Participants
Any number of adults, teens, families with children 6 years and up, or school/youth groups ages 8 and older.



Location and Timing
At a star party, this activity can take from one minute to as long as you wish to observe.

Included in This Activity

Detailed Activity Description
Background Information
FAQ Sheet
Master of July/Aug. Star Maps
List of known black holes

Materials Needed
- Copies of Black Hole Star Maps for your visitors with FAQs printed on the back (July/Aug star map included below)
    - For other times of year, download Star Maps here (450 KB): http://nightsky.jpl.nasa.gov/docs/BHStarMaps.pdf
- *(Optional)* Telescopes

Set Up Instructions
Make as many copies of the 2-sided handout as you need. The current star map is printed on one side and the Black Hole FAQ's are printed on the other side. You may want to copy your club information on the back of the star maps, under the FAQ's. For reference, you may want to print the list of known black holes.

Detailed Activity Description

Leader's Role	Participants' Roles
Observing the location of black holes (naked eye): **Presentation Tip:** Be sure to ask your visitors if they think they will see the black hole. If they don't realize they won't actually see it, they may be disappointed. *To Say:* When we look up in the sky do you think we are going to be able to see the black hole itself? No, we won't – why not? Right – black holes are invisible to the eye. *To Do:* Hand out "Where are the Black Holes?" star map. *To Say:* But we can use this map to see where astronomers have actually discovered black holes. How do you suppose astronomers know they are there? Right - using some of the techniques we already discussed, like detecting strong x-rays or seeing companion stars orbiting the invisible black hole. *To Do:* Provide instruction on how to use star maps. Point to the locations of black holes. This is a naked eye activity. *To Say:* On the back of the star map, you'll find some FAQ's about black holes.	 No. Black holes don't give off any light. Takes star map. X-rays – motions of nearby stars? Learns to use star map.

Observing the location of black holes (Telescope): You may want to continue and have some of the other club members with telescopes show galaxies known to harbor supermassive black holes at their centers. And if M15 is visible, you might want to show that globular cluster in a telescope. The companion stars of stellar-mass black holes, except for the companion of black hole Cygnus X-1, are not visible in backyard telescopes.	

Background Information

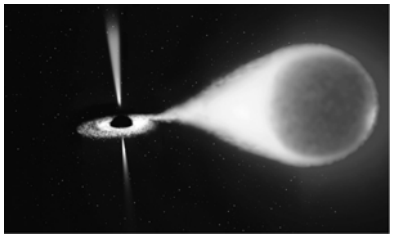
There will be nothing to see at the locations of black holes in the sky. Their companion stars and parent galaxies are too dim to see with the unaided eye. But seeing the location in a constellation makes the existence of black holes real to your visitors.

As for telescope viewing of black hole locations, the parent galaxies of the supermassive black holes are certainly visible in the telescope (under the right skies). And, if it is July through December, the globular cluster M15, which harbors a mid-mass black hole, is visible in the scope. Cygnus X-1's companion star (visible in the evening June through mid-December) is really the only one visible in backyard telescopes, at a visual magnitude of 9.

For more information on how scientists discover black holes:
http://cfa-www.harvard.edu/seuforum/bh_reallyexist.htm

Review the "Black Hole FAQ's" page that is to be printed on the back of the star maps. (Next page)

BLACK HOLE FAQ's



1. **What is a black hole?** A black hole is a region of space that has so much mass concentrated in it that there is no way for a nearby object to escape its gravitational pull. There are three kinds of black hole that we have strong evidence for:
    a. Stellar-mass black holes are the remaining cores of massive stars after they die in a supernova explosion.
    b. Mid-mass black hole in the centers of dense star clusters
    c. Supermassive black hole are found in the centers of many (and maybe all) galaxies.
2. **Can a black hole appear anywhere?** No, you need an amount of matter more than 3 times the mass of the Sun before it can collapse to create a black hole.
3. **If a star dies, does it always turn into a black hole?** No, smaller stars like our Sun end their lives as dense hot stars called white dwarfs. Much more massive stars end their lives in a supernova explosion. The remaining cores of only the *most* massive stars will form black holes.
4. **Will black holes suck up all the matter in the universe?** No. A black hole has a very small region around it from which you can't escape, called the "event horizon". If you (or other matter) cross the horizon, you will be pulled in. But as long as you stay outside of the horizon, you can avoid getting pulled in if you are orbiting fast enough.
5. **What happens when a spaceship you are riding in falls into a black hole?** Your spaceship, along with you, would be squeezed and stretched until it was torn completely apart as it approached the center of the black hole.
6. **What if the Sun became a black hole without gaining or losing any mass?** The Sun can't turn into a black hole, but if it did, the Earth would get very dark and very cold. The Earth and the other planets would not get sucked into the black hole; they would keep on orbiting in exactly the same paths they follow right now.
7. **Is a black hole a portal ("wormhole") to another part of the universe?** In some science fiction shows, people sometimes travel through wormholes. This leads many people to think black holes are wormholes and therefore lead to other places. There is no evidence that wormholes exist.
8. **Can I see a black hole?** No. The light produced or reflected by objects makes them visible. Since no light can escape from a black hole, we can't see it. Instead, we observe black holes indirectly by their effects on material around them.
9. **What evidence is there that black holes exist?** Fast-moving stars orbiting "unseen" objects and strong X-rays emitted from a very small area of space. NASA missions and projects are in the process of discovering more about black holes.

For more info:
http://cfa-www.harvard.edu/seuforum/blackholelanding.htm

THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

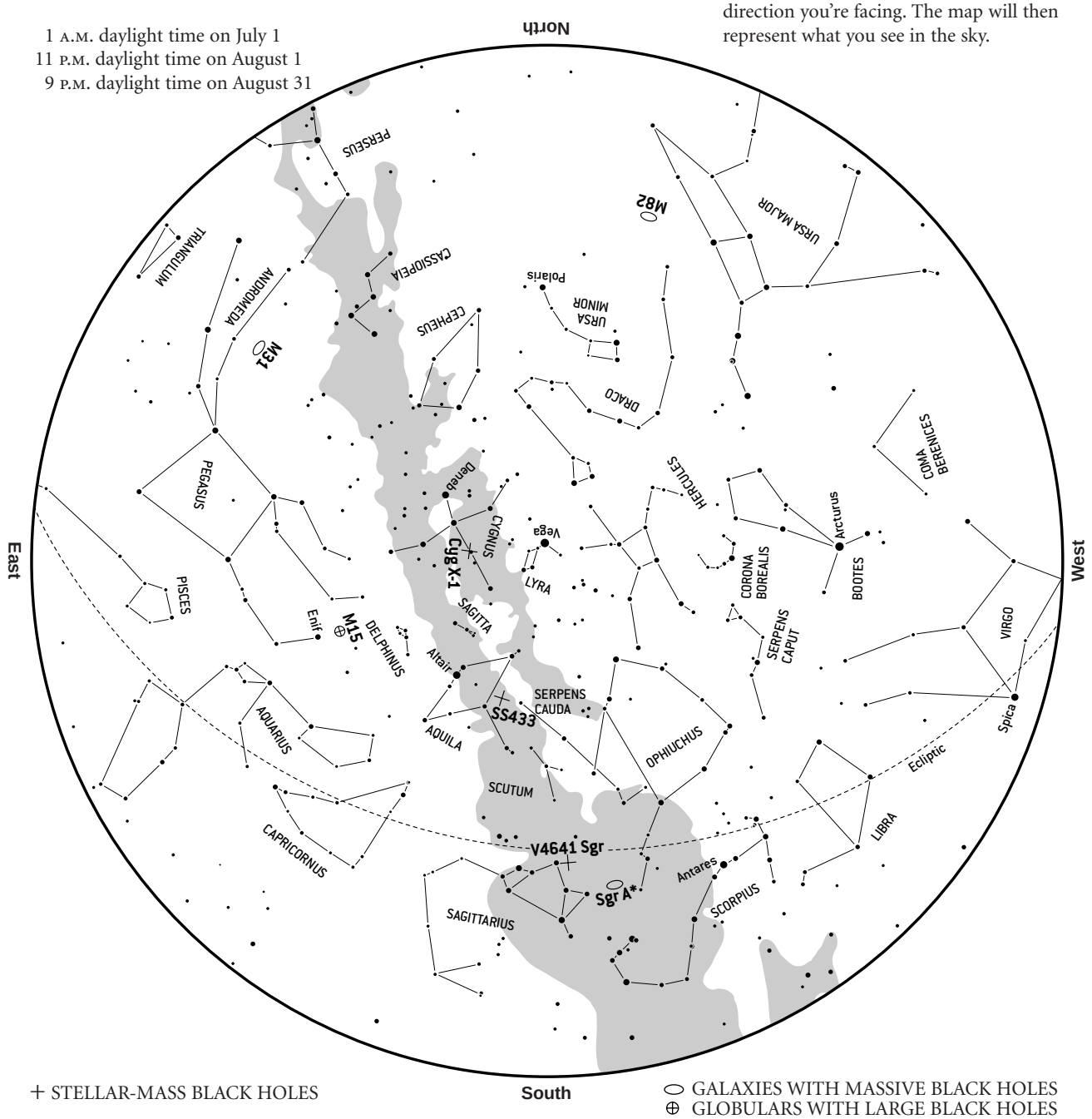
Where Are the Black Holes?

July/August

The all-sky map represents the night sky as seen from approximately 35° north latitude at the following times:

1 A.M. daylight time on July 1
11 P.M. daylight time on August 1
9 P.M. daylight time on August 31

To locate stars in the sky, hold the map above your head and orient it so that one of the four direction labels matches the direction you're facing. The map will then represent what you see in the sky.



+ STELLAR-MASS BLACK HOLES

Object	Distance	Mass
V4641 Sagittarii	32,000 light-years	7 Suns
SS433	16,000 light-years	10 Suns
Cygnus X-1	7,000 light-years	10 Suns

⬭ GALAXIES WITH MASSIVE BLACK HOLES
⊕ GLOBULARS WITH LARGE BLACK HOLES

Object	Distance	Mass
M31	2.5 million light-years	30 million Suns
M82	12 million light-years	> 460 Suns
Sgr A*	26,000 light-years (center of Milky Way Galaxy)	2 million Suns
M15	33,000 light-years	2,500 Suns

Black Hole Locations

Stellar Mass Black Holes (in the Milky Way Galaxy)

Name	RA (2000)	DEC	m(V)	Companion	Orbit	Distance	Scaled distance **	Mass (Solar)	Type
						light years	Miles		
V518 Per	04 21 42.8	+32 47 24	13.2	M4	5h	6500	163	4 solar	Low Mass X-ray Binary (LMXRB)
V616 Mon	06 22 44	-00 20 45	18.2	K4V	7.75h	2700	68	11 Solar	LMXRB
MM Vel	10 13 36	-45 04 32	14.9	K6V	6.9h	10,000	250	4.5 solar	LMXRB
Nova Sco 1994	16 54 00	-39 50 45	14.4	F5IV	15hr	10,000	250	6 solar	LMXRB
Nova Oph 1977	17 08 14	-25 05 32	21	K5V	12.5hr	33,000	825	7 solar	LMXRB
V2293 Oph	17 19 37	-25 01 03		M3V(?)		7500	188	>5	LMXRB
MACHO-98-BLG-6	17 57 33	-28 42 45	16	isolated	N/A	6,500	163	6 solar	gravitational lensing event
V4641 Sgr*	18 19 22	-25 24 25	14???	B9III	68hr	32,000	800	7 solar	microquasar
SS433	19 11 50	+04 58 57	14.2	AI?	13d	16,000	400	10 solar	BH with jet (microquasar)
V1487 Aql	19 15 11	+10 56 45		K/M	820 hr	39,000	975	14 solar	LMXRB
Cygnus X-1	19 58 21.7	+35 12 06	8.95	O9I	5d	7,000	175	10 solar	High mass X-ray binary
Nova Vul 1988	20 02 50	+25 14 11	21	K5V	8.2hr	6,500	163	7 solar	LMXRB
V404 Cyg	20 24 04	+33 52 03	11.5 (B)	K0IV	6d	8,000	200	12 solar	LMXRB

***Nearest Black Hole Candidate**
Looking at this list, the nearest known black hole is V616 Mon at 2700 light years. Astronomy Picture of the Day from January 17, 2000 (http://antwrp.gsfc.nasa.gov/apod/ap000117.html) quotes 1500 light years to V4641 Sgr. There is not a complete agreement on the distance to V4641 Sgr. Several professional papers quote 7 to 12 kpc (22,000 to 39,000 ly.) This companion star also varies in brightness from 12 down to 13.5.

**
Qtr-Sized Solar System and N. America-sized Galaxy. (1mile=40 lyr. Scale from "Our Place in Our Galaxy")

Massive & Supermassive Black Holes in Galaxies

Name	RA	Dec	m(V)	galaxy type	Distance (Mlyr)	CD dist (feet/miles)	Mass (Solar)	
M110	00 40 25	+41 41 16	8.9	E6	2.3 M.lyr.	9 ft	90,000	intermediate mass
M31	00 42 44	+41 16 08	4.4	Sb	2.5 M.lyr.	10 ft	30 million	
M33	01 33 51	+30 39 36	6.3	Sc	2.6 M.lyr.	10.4 ft	900,000	
NGC 821	02 08 21	+10 59 42	11.7	E6	79 M.lyr.	315 ft	37 million	
M77	02 42 41	-00 00 47	9.6	Sb	49 M.lyr.	196 ft	15 million	
M82	09 55 54	+69 40 57	9.2	Irr	12 M.lyr.	48 ft	>460	intermediate mass
NGC 3115	10 05 14	-07 43 07	11	S0	32 M.lyr.	128 ft	1 billion	
M105	10 47 49	+12 34 54	10.2	E1	35 M.lyr.	140 ft	100 million	
Mkn 421	11 04 27	+38 12 32	13.3	S? blazar	370 M.lyr.	1480 ft	190 million	
NGC 4151	12 10 33	+39 24 20	11.2	Sa	50 M.lyr.	400 ft	10 million	
NGC 4459	12 29 00	+13 58 43	11.6	Sa	52 M.lyr.	208 ft	70 million	
3C 273	12 29 06	+02 03 08	12.9	quasar	2146 M.lyr.	1.6 mile	billion	
NGC 4473	12 29 48	+13 25 45	11	E5	51 M.lyr.	204 ft	80 million	
M87	12 30 49	+12 23 28	9.6	E1	52 M.lyr.	208 ft	3 billion	
NGC 4579	12 35 12	+12 05 36	11.5	Sab	55 M.lyr.	220 ft	2 million	
M104	12 39 59	-11 37 23	9	Sa	30 M.lyr.	120 ft	500 million	
NGC 5033	13 11 08	+36 51 48	10.7	Sc	61 M.lyr.	244 ft	500 million	
NGC 5845	15 06 01	+01 31 01	13.5	E3	84 M.lyr.	336 ft	240 million	
NGC 6251	16 32 32	+82 32 17	14.3	E2	300 M. lyr.	1200 ft	600 million	
Mkn 501	16 53 53	+39 45 36	13.8	E1 blazar	420 M.lyr.	1680 ft	1.6 billion	
3C 371	18 06 06	+69 49 28	14.4	E? blazar	620 M.lyr.	2480 ft	320 million	
NGC 7052	21 18 33	+26 26 49	14	E4 radio galaxy	190 M.lyr.	760 ft	330 million	
BL Lac	22 02 43	+42 16 40	14.5	blazar	937 M.lyr.	3748 ft	billion	
NGC 7457	23 01 00	+30 08 43	11.8	S0	43 M.lyr.	172 ft	3.5 million	
Sgr A*	17 45 40	-29 00 29	N/A	SBb	26000 lyr.	***->	2 to 4 million	Central BH in Milky Way

Intermediate or Mid-Mass Black Holes

M31 G1	00 42 44	+41 16 08	13.7	globular cluster in Andromeda Galaxy	2.3 M.lyr.	9 ft	90,000	in Andromeda Galaxy
M15	21 29 58	+12 10 01	3	globular cluster	33,000 lyr.	***->	2,500	in Milky Way Galaxy

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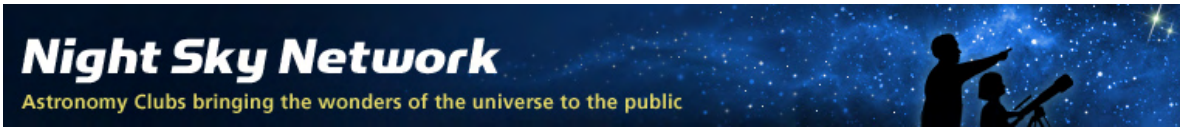

The Night Sky Network is a nationwide coalition of amateur astronomy clubs bringing the science, technology, and inspiration of NASA's missions to the general public.

We share our time and telescopes to provide you with unique astronomy experiences at science museums, observatories, classrooms, and under the real night sky.
http://nightsky.jpl.nasa.gov

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